SSERVI-ESF14-159

Author: KEITH BENNETT

POSTER

Missions (Including Commercial)

ACCESSING PDS DATA IN PIPELINE PROCESSING AND WEB SITES THROUGH PDS GEOSCIENCES ORBITAL DATA EXPLORER'S WEB-BASED API (REST) INTERFACE

ODE Overview: The Orbital Data Explorer (ODE) is a web-based search tool (http://ode.rsl.wustl.edu) developed at NASA's Planetary Data System's (PDS) Geosciences Node (http://pds-geosciences.wustl.edu/). Through ODE, users can search, browse, and down-load a wide range of PDS Mars, Moon, Mercury, and Venus data (A detailed list of current ODE holdings can be found at http://wufs.wustl.edu/ode/odeholdings/index.html).In the fall of 2012, the Geosciences node introduced a simple web-based API that allows non-PDS web and processing tools to search for PDS products, obtain meta-data about those products, and download the products stored in ODE's meta-data database (http://oderest.rsl.wustl.edu/live). The first version is now used by several teams in periodic processing and web sites.REST Interface Overview: The ODE Representational State Transfer (REST) interface is a simple web-based interface allowing external users and tools to access the ODE metadata and products. REST query. The current ODE REST interface only supports read-only GET functions. The query format basically breaks down into several components including target, query type, output format, and query parameters. A simple query will return a variety of data such as a list of products, product metadata, product footprints, product browse images, or even the products themselves. Results are typically in XML or JSON format except in cases where the return is an image. Product file requests return one or more web-addresses for directly downloading the file(s). Example. A simple example of using the REST interface to find how many HiRISE Version 1.1 RDR products exist within a latitudes 0 to 10 and longitudes 0 to 10: http://oderest.rsl.wustl.edu/live?target=mars&query=products&results=c&iid=HIRISE&pt=RDRV11&maxlat=10.0&minlat=0.0&westernlon=0.0&easternlon=10.0 Returns (formatted for readability):<ODERsults><Status>Success</Status><QuerySummary><Date>2013-12-18T09:07:08.197</Date><target>MARS</target><query>PRODUCT</query><westernlon>0</westernlon><easternlon>10</easternlon><minlat>0</minlat><maxlat>10</maxlat></QuerySummary><Count>353</Count></ODEResults>REST Product Queries: The ODE REST interface allows external tools to query ODE for a wide range of data including product metadata. Product metadata, which varies depending on the data set, includes observation times, creation times, map resolutions/scales, observation angles, solar longitudes, solar distances, spacecraft clock times, version numbers, activity ids, producer information, and links to instrument web sites. Queries can be limited by instrument hosts, instruments, product types, data set ids, location, features, observation times, and creation times. Location limits can be based on the "intersecting", "contains", or "contained by" geographic relationships between products intersecting a surface lat/lon bounding box or footprint. Using a series of queries can produce a very sophisticated result that find spatial and temporal relationships between various products.Comments on ODE and questions on REST access can be sent to bennett@wustl.edu.

Author: ROBERT CATALDO
ORAL

Missions (Including Commercial)

Low-Power Radioisotope Power Systems for Future Smaller Spacecraft and Low-Cost Missions

Low-Power Radioisotope Power Systems for FutureSmaller Spacecraft and Low-Cost MissionsBackgroundRadioisotope Power Systems (RPS) have enabled many NASA missions during the past 50 years to very harsh and challenging destinations of the solar system, from the Moon to the solar heliosphere to interplanetary space, supplying both electrical energy and useful heat. An RPS utilizes the heat generated from natural decay of plutonium-238 via heat-to-electric conversion devices. In particular, the long 87.8-year half-life decay of Pu-238 and the robust nature of thermoelectric devices allow long-lived missions, such as experienced with the Voyager 1 and 2 spacecraft, both still operating more than 35 years after launch. Additionally, the power system essentially supplies its own energy source, making it enabling for missions with destinations far from the Sun or on planetary surfaces, immune from occultation caused by clouds, dust or planetary surface features.All past NASA RPS missions have used radioisotope thermoelectric generators (RTG) that typically utilize a series/parallel combination of thermoelectric elements for heat to electric conversion. The current thermoelectric technology employed, such as the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), has an efficiency of approximately 5.0%, producing 110 We from 1,975 Wth. However, mission concepts that would utilize a large RTG or multiple RTGs are typically larger spacecraft and certainly more costly, with a lower frequency of occurrence. Over the past several years, smaller and less costly spacecraft concepts have been discussed that could provide a higher rate of interesting missions envisioned by the science community.IntroductionTo this end, the Radioisotope Program Office at the Glenn Research Center is exploring the science mission needs for low-power RPS <1.0 We. The more recent interest and developments in small spacecraft that could ride share on other larger missions for example, has a potential need for the low-power RPS. One potential low-power RPS would utilizes the flight-proven (e.g., Cassini, MER rovers) Radioisotope Heater Units (RHUs), which produce approximately 1.0 Wth with 2.7 gm PuO2. Concepts have been developed using a single and multiple RHUs. The single RHU-RPS engineering unit was developed by Hi-Z Inc., built and tested for high "g" applications required for previously proposed Mars penetrator missions. Other concepts were investigated that used multiple RHUs that could produce electric power approaching 0.5 We with 10 RHUs. Therefore flexibility exists to tailor such designs. In addition, these systems could be electrically placed in parallel to match spacecraft power system requirements.In addition to continuous power output, the RHU-RPS would also serve to provide heat to critical spacecraft components and instruments, thus allowing a potentially simpler thermal management system envisioned for a small, low-cost spacecraft.

SSERVI-ESF14-161
Author: YOUNG-JUN CHOI
ORAL

Missions (Including Commercial)

Scientific Aspects for Korean Lunar Exploration

Korea is going to launch the first orbiter in 2017 and both orbiter and lander around 2020 for lunar exploration. Since the surface of the Moon has been a witness of the Solar System history, currently lunar whole surface map in visible spectral range was completed through a camera of the latest lunar missions. However, because lunar surface continuously changes by impacts of meteorites, the surface should be observed again. In addition, it would be useful to use multi-wavelength polarimetry in visible range or to measure surface reflectance in ultraviolet spectral range. Polarization of lunar surface depends on both albedo and surface roughness, which is related to thermal properties results from infrared (IR) observation. Further IR observations are required for studying mineralogy and confirming the existence of water ice at permanent shadow region in both poles. IR spectral range for scientific study of lunar surface is classified as three regions according to recently results of the study. In the first range, 0.5-1.5_, absorption lines of Olivine, Pyroxene can be detected. Water, ice, OH absorption lines can be detected in 2.6-3.6 _range. Christian Feature (CF), in 7-9 _ range, shows silicate mineralogy. We will briefly discuss about current Korean lunar exploration status and its scientific aspects.

Author: PAMELA CLARK
ORAL

Missions (Including Commercial)

LunarCubes: Progress on LWaDi orbiter

We are in the process of developing a payload and bus concept for high priority science-driven missions of lunar exploration using an architecture known as LunarCube, with focus on resolving the challenges of using a standardized platform and existing cubesat hardware and maintaining a cubesat form factor for CubeSats missions to operate near or on the Moon. We focus on architecture for lunar exploration because of its proximity and accessibility as a stepping stone to the rest of the solar system, combined with the great international scientific interest in the Moon and its suitability as an analog with extreme range of conditions and thus an ideal technology testbed for much of the solar system.Three concepts are under consideration, including a lunar polar outflow impactor, an observatory pathfinder, and a lunar orbiter. Here, we focus on LWaDi (Lunar Water Distribution) orbiter. The goal of LWadi is to determine the nature of lunar water and water component distribution as a function of time of day, latitude, and regolith composition. The payload is a compact broadband IR detector with measurement capability inclusive of the 1.3 to 3.7 micron range and high spectral resolution (10 nm), capable of distinguishing the many features associated with water and water components in various forms, as well as mineral signatures, associated with this region. The instrument, with heritage from OSIRIS-REX OVIRS, has compact optics that include a linear variable filter and an adjustable iris to maintain a 10 km spot size regardless of altitude and a built in cryocooler to maintain the detector at 140K. The instrument package is approximately 1.5U and 2 kg. The high inclination, highly elliptical (7 hour) equatorial periapsis orbital trajectory is designed to provide repeated coverage of the same representative selected surface features at different times of day (from dawn to dusk) for each lunar cycle. We have completed preliminary system definition and design activities. The result is a 6U concept which includes state of the art components, including the GSFC SpaceCube Mini C&DH and INSPIRE X-band communication system. Other components, developed for LEO cubesats, will need to be modified as necessary to provide radiation mitigation required for deep space operation. Thermal modeling indicates we should be able to maintain the temperature inside the spacecraft between 7 and 29 degrees, and with additional thermal shielding, to maintain the optics box below 240K. We are initiating thermal and vibrational testing of a breadboard representing the payload under the range of conditions that would be experienced in lunar orbit. Our long-term goal is cost-effective, generic design for a broad cross-section of future high priority space or surface payloads for planetary, heliophysics, and astrophysics disciplines.

SSERVI-ESF14-163

Author: PAMELA CLARK

POSTER

Missions (Including Commercial)

Compact and/or Cryogenic Lunar Surface Packages

Much smaller bodies orbit most stars, thus planets and not stars are the most common bodies in the universe. Solid body formation and modification processes are a key to understanding cosmic processes: the new cosmology. Volatiles, including water and simple organics and their ices, are unexpectedly ubiquitous on the surfaces of Mercury and the Moon, especially at their poles, as well as asteroids. Implications are that surface processes involving interactions of volatiles with space radiation, dust and charged particles are playing important roles in surface processes and potentially in regolith and planetary formation, influencing processes ranging from space weathering to accretion to biological precursor formation. The development of instrument packages capable of continuous operation on planetary surfaces is critical for understanding these processes.In support of Project Constellation, we developed a concept for an ALSEP-like stand-alone lunar surface instrument packages without dependence on radioisotope-based batteries: LEMS (Lunar Environmental Monitoring Station). And initial attempt to design an environmental monitoring package conventionally with a solar/battery based power system led to a package with a unacceptably large mass (500 kg) of which over half was battery mass. We eventually reduced the mass to 100 kg using radiation hard, cold temperature electronics, innovative thermal balance strategies using multi-layer thin reflective/insulting materials, a gravity-assisted heat pipe, and a limited night time duty cycle (Clark et al, 2011). Using existing cubesat components battery technology, similar thermal/mechanical, compact versions of several instruments, we estimate a 12U concept for such stations with 4-5U for payload.Major challenges in developing such systems remain, however, particularly in regard to thermal design and power storage. Recently developed thermal protection technologies such flexible polymer aerogel, more compact heat pipes utilizing ionic liquids, more efficient, radiation and thermal degradation tolerant solar panels may improve thermal protection with lower mass and volume penalty. However, the biggest challenge is in energy storage without the use of RTGs, which so far has been met by limiting power consumption through hibernation or the limited duty cycle presented here. The use of RTGs, with their limited availability and high cost, is far from an ideal solution. The biggest potential may lie in High Temperature Superconductors, now being used in power generation, storage, and transmission here on Earth. HTS systems should be scalable in theory.

Author: RUSSELL COX
ORAL

Missions (Including Commercial)

LunarCube Based Transient Asteriod and Planetesimals (TAPs) Observatory

Resent calculations by Bill Bottke of Solar System Exploration Research Virtual Institute (SSRVI) suggest that there may be as many as ten to twenty, one to two meter sized asteroids entering the Earth - Moon system each year. Many of these bodies may be temporarily captured for several weeks or months in chaotic trajectories that are likely to be energetically close to the Earth-Moon Lagrange points affording an opportunity for rendezvous and interaction several times each year with a previously unobserved population of Near Earth Objects (NEOs). This presentation will outline an observation program consisting of several generations of increasingly complex ESPA Ring Carrier \ iCubeSat platforms capable of interacting with 50 to 100 NEOs over a ten to fifteen year timeframe. The proposed architecture would place an ESPA based carrier at an Earth - Moon Lagrange point with ten to twenty iCubeSat based chaser spacecraft. The carrier would provide propulsion, power, communication, navigation and computational support until a reachable NEO is detected and an individual chaser is launched, then the chaser must be able to track and rendezvous with a one meter sized object in a nearby chaotic trajectory. This rendezvous capability will be critical for future crewed and uncrewed missions to NEOs. Each chaser iCubeSat would have its own instrument suite that would include penetrators or robot arm(s) to interact with the object to ascertain its chemical and physical properties. Ideally one would launch 3 to 5 carriers over a ten to fifteen year timeframe to take advantage of improving technology and knowledge of the NEO population to be studied.The knowledge gained would be very valuable to both the planetary science and asteroid mining communities. One simple and critical observation that can only be made by an architecture like this is to understand the relative abundance of differing asteroid morphologies. It is believed that asteroids have internal structures ranging from solid rocks to rubble piles to "dust bunnies" and very likely the only way to distinguish between these cases and to get good statistics on their relative abundances among NEOs and asteroids would be to directly interact with tens or hundreds of individual bodies. Additionally, "dust bunnies," if they exist, would very likely be good analogs or examples of the earliest objects that became planetesimals in the early accretion disk and very little is known about the first stages of aggregation in planetary formation.

Author: RUSSELL COX

ORAL

Missions (Including Commercial)

The International Lunar Geophysical Year: 2017-2018

The Lunar Renaissance 2007 - 2020: Starting n 2007 eleven spacecraft from many countries transformed our understanding of the Moon reveling a dynamic destination rich with new scientific and commercial opportunities that can unlock the entire solar system for all mankind. In 2017 - 2018, Russia, China, Korea and the US all plan to have active national missions in cislunar space. There are as many as twenty or more private missions being planed and there will be many secondary payloads and LunarCube missions riding along. Thus, there are going to be many nations, many organizations and many, many people involved in active missions in Cislunar space in the eighteen months from July 2017 to December 2018 the 60th anniversary of the International Geophysical Year 1957 - 1958. Proposal: We are proposing to create The International Lunar Geophysical Year 2017 - 2018 (ILGY) to coordinate many of these activities. Like the International Geophysical Year (IGY) of 1957 - 1958, that launched the space age, the ILGY will focus on joint scientific collaboration and coordination while setting the stage for future political and commercial cooperation that will be critical for the peaceful and profitable exploration and exploitation of the cislunar environment for all mankind. Initial Activities in 2014: Flexure Engineering and The Select Investor, Inc. will be providing the initial organization and promotion of the ILGY providing many opportunities for collaboration and discussion through the Lunar Intiatives..The Lunar Initiatives•The Lunar Workshops•The Lunar Special Interest Groups (SIGs)•The Lunar Challenges•The Lunar Incubators•The International Lunar Geophysical Year In addition, we will create a public clearing house on the internet for missions, instruments and scientific objectives expected to be operational in the ILGY timeframe.We will be establishing and running the monthly ILGY SIG that will explore these themes : Scientific Collaboration•Active Missions \ Scientific Objectives•Terrestrial Scientific Collaborations•Future Missions \ Scientific ObjectivesMission and Organizational Coordination•National Missions•Private or Commercial Missions•Terrestrial OrganizationsPolitical, Legal and Standards •Treaties and other mechanisms to ensure open access for all mankind•Legal framework for scientific and commercial activities•Technical standards to encourage coexistence, interoperability and reuseActivities in 2015 - 2016: Our goal will be to provide the information we have collected and the support systems we have created through The Lunar Initiatives to existing international political, professional and standards bodies to help in the creation of collaborative, coordinated strategies to deal with the tsunami of activity that is building now and will crash onto the Lunar shores in the second half of this decade. Conclusions: The Lunar Renaissance is underway. The ILGY would help smooth and accelerate global collaboration and exploration providing scientific and commercial benefits for all mankind.

Author: BRIAN DAY
POSTER

Missions (Including Commercial)

Ground-Based Lunar Meteoroid Impact Observations and the LADEE Mission

What was once thought a spurious phenomenon with little scientific evidence - a form of Transient Lunar Phenomena, point flashes from lunar meteoroid impacts are now a relatively commonly observed phenomenon as shown by the many confirmed observations by both professional and amateur groups. In addition to the natural phenomena, several artificial impacts of spacecraft on the moon over the last fifteen years have yielded valuable information on the physics of impacts as well as evidence of sub-surface water ice. A coordinated effort between NASA and ground-based observers was recently undertaken to assist in the scientific efforts of NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE) mission. These efforts involved observers from around the world. They yielded geographic and temporal coverage that expanded upon and supplemented that which was provided by the Automated Lunar and Meteor Observatory (ALaMO) operated by NASA's Meteoroid Environment Office (MEO). They resulted in confirmed recordings of lunar meteoroid impacts during the LADEE mission that were not observable by ALaMO.Among the data collected by LADEE during the science phase of its mission is that of the presence of lunar dust aloft, along with changes in the dust's concentration, thought to be indicative of "flak" from meteoroid impacts. The lunar environment provides an excellent laboratory to study phenomena related to hypervelocity impacts, and correlations between ground-based observations of lunar impacts and in situ measurements of changes in dust concentration have the potential to contribute valuable information on the physics of hypervelocity impacts. Collaboration between the LADEE mission personnel and ground based observers equipped for the task is an excellent example of professional-amateur collaborations. As part of this campaign, NASA's Solar System Exploration Research Virtual Institute (SSERVI) conducted an online "Workshop Without Walls" for interested parties from around the world to outline the plans and procedures for making scientifically useful observations. This workshop brought together members of the LADEE mission, MEO, the Association of Lunar and Planetary Observers, and a number of experienced impact observers. The workshop was recorded and archived by SSERVI to be used as a resource for continued professional-amateur collaborations in lunar meteoroid impact studies during and continuing beyond the LADEE mission.

Author: SIMONE DELL'AGNELLO
ORAL

Missions (Including Commercial)

Next-Generation Laser Retroreflectors for Solar System Exploration, Geodesy and Gravitational Physics

We are developing next-generation laser retroreflectors for solar system exploration, geodesy and for the precision test of General Relativity (GR) and new gravitational physics: a micro-reflector array (INRRI, Instrument for landing-Roving laser Retroreflectors Investigations), a midsize reflector array, CORA, a large single, large retroreflector (MoonLIGHT, Moon Laser Instrumentation for General relativity High accuracy Tests). They will be fully characterized at the SCF_Lab (Satellite/lunar/gnss laser ranging and altimetry Characterization Facilities Laboratory), a unique and dedicated lab infrastructure of INFN-LNF, Frascati, Italy (www.lnf.infn.it/esperimenti/etrusco/). Research program:1. Laser retroreflector devices to determine landing accuracy, rover positioning during exploration and planetary/moons surface georeferencing. These devices will be passive, wavelength-independent, long-lived reference point enabling the performance of full-column measurement of trace species in the Mars atmosphere by future space-borne lidars. These measurements will be complementary to highly-localized measurements made by gas sampling techniques on the Rover or by laser back-scattering lidar techniques on future orbiters and/or from the surface. INRRI will also support future science experiments of quantum physics laser communications exploiting the polarization states of laser photons, carried out among future Mars Orbiters and Mars Rovers. This will be possible also because the INRRI laser retroreflectors will be metal back-coated and, therefore, will not change the photon polarization. The instrument is also being proposed for landings on the Moon (two Google Lunar X Prize Missions, namely Moon Express and Astrobotic). The added value of INRRI is its low mass, compact size, zero maintenance and its usefulness for any future laser altimetry, ranging, communications, atmospheric lidar capable Mars orbiter, for virtually decades after the end of the Mars surface mission, like the Apollo and Lunokhod lunar laser retroreflectors.2.Tests of GR with LLR on MoonLIGHT reflector (see abstract of D. Currie)3.Extension of program to:•Mars, Phobos and Deimos•Jupiter and Saturn icy/rocky moons•Near Earth Asteroids4.Development of new gravitational physics models and set experimental constraints using also laser ranging and laser reflectors in the solar system:•Extension of General Relativity to include Spacetime Torsion•Non-Minimally Coupled (NMC) Gravity, non minimal coupling between matter and curvature (so-called f1+f2 theories)5. Strong synergism with:•Ground stations of International Laser Ranging Service (Apache Point Lunar Laser-ranging Operation, in the US; MLRO, Matera Laser Ranging Observatory in Italy)•Data Laser-Comm.; mining of moons and asteroids•Search for exolife on Jupiter/Saturn moons.

SSERVI-ESF14-168

Author: THOMAS EUBANKS

ORAL

Missions (Including Commercial)

The Solar Scout: A Solar Sail Asteroid Prospector

Asteroid mining will require the direct, in situ, prospecting of Near Earth Objects (NEO). An ideal asteroid prospector would be able to visit a number of mining candidates in sequence, each requiring a substantial velocity change, typically several km / second for each new NEO. A Solar Sail, which requires little or no expendable propulsion, is the natural choice for an asteroid prospector, as fuel constraints would severely limit the number of asteroid candidate visits possible using chemical or ion propulsion. This talk will describe the Solar Scout™, a solar sail spacecraft intended for asteroid prospecting. The current spacecraft design has a mass of < 60 kg, a sail extent of 40 x 40 meters and a nominal payload mass of 5 kg. With a Solar Sail for propulsion, the Solar Scout could visit between one and two mining candidates per year, depending on the velocity change required and the duration of each asteroid rendezvous.The Solar Scout payload would include a a visual camera, for near-rendezvous optical navigation, and one or more sail cameras (for monitoring wrinkles and billows in the sail). Potential instruments include a magnetometer (for the detection of metals), infrared spectrometers (to distinguish between different geological materials), and Asteroid Radio Tomography (ART, a passive or active system for detecting internal water and buried objects). To save weight, these instruments would be integrated into the sail structure (i.e., the magnetometer would be located at a sail vertex, and the ground penetrating radio antennae could use the sail as a ground plane. Other instruments (such as gamma ray backscatter detectors) would likely not fit within the instrument mass and power budgets. The results from a NEO prospector would certainly be of scientific interest; as is common in geophysical prospecting; Asteroid Initiatives intends to seek arrangements with NASA allowing for the immediate release of a portion of the data acquired to the scientific community.

Author: BENJAMIN GREENHAGEN

ORAL

Missions (Including Commercial)

The Extreme Thermal, Thermophysical, and Compositional Nature of the Moon Revealed by the Diviner Lunar Radiometer

After nearly five years in operation, and well into its extended science mission, the Diviner Lunar Radiometer has revealed the extreme nature of the Moon's thermal environments, thermophysical properties, and surface composition. This presentation will highlight contributions from members of the Diviner Science Team addressing a diverse range of scientific questions from the extended science mission.Diviner is the first multispectral thermal-infrared instrument to globally map the surface of the Moon. To date, Diviner has acquired observations over nine complete diurnal cycles and five partial seasonal cycles. Diviner daytime and nighttime observations (12 hour time bins) have essentially global coverage, and more than 80% of the surface has been measured with at least 6 different local times. The spatial resolution during the mapping orbit was ~200 m and now ranges from 150 m to 1300 m in the current elliptical "frozen" orbit. Calibrated Diviner data and global maps of visible brightness temperature, bolometric temperature, rock abundance, nighttime soil temperature, and silicate mineralogy are available through the Planetary Data System (PDS) Geosciences Node.Diviner was designed to accurately measure temperatures across a broad temperature range from midday equatorial regions such as the Apollo landing around 400K, typical nighttime temperatures of less than 100K at night, and extreme permanent shadowed regions colder than 50K. The coldest multiply-shadowed polar craters may have temperatures low enough to put constraints on lunar heat flow. Diviner data have also been used to estimate the thermal properties of non-polar permanently shadowed regions.Diviner is directly sensitive to the thermophysical properties of the lunar surface including nighttime soil temperature, rock abundance, and surface roughness. During the extended science mission we have produced higher fidelity maps of these properties and used them to investigate anomalous rock abundances, "cold spots" with fluffier surface layers, regolith formation and evolution, and surface roughness.Diviner was designed to characterize the Christiansen Feature (CF) and constrain lunar silicate mineralogy. Recent efforts in this area have focused on improving the quality of Diviner's mid-infrared "photometric" correction, groundtruthing Diviner observations to Apollo soils, using Diviner's longer wavelength channels to improve constraints on olivine, and combining Diviner with visible and near-infrared datasets to enhance interpretations of pyroclastic deposits, plagioclase-rich regions, high silica regions, and space weathering.A major effort during the extended science mission has been to create a "Foundation Dataset" (FDS) to improve the quality and usability of Diviner data available in PDS. To improve the radiometric accuracy, we reexamined Diviner's pre-flight ground calibration and revised the in-flight calibration methodology. Diviner level 1b activity and quality flags have been modified based on critical reviews from Diviner data users. Finally, we used the new level 1 data to produce a wide range of level 2 and 3 gridded datasets that are more accurate, better organized, and include important geometric and observational backplanes. Delivery of the Diviner FDS to PDS is expected to begin in 2014.

SSERVI-ESF14-170

Author: UGUR GUVEN ORAL

Missions (Including Commercial)

ANALYTICAL EXPLORATION OF MANNED SPACE MISSION TO HELIOPAUSE

One of the most important things for the development of mankind is the various advancements in space technology. This is essential, as advancements in space technology have also opened up new frontiers in the development of our modern world as well. Everything that we learn from our universe has been utilized in some way of advancing our technology in our everyday lives as well. Each step in space exploration, takes humanity closer to the brink of significant advancement. Hence, the next logical step in space exploration would be to start exploring the outer fringes of our solar system. The outer boundaries of the solar system will provide the space programs of the world with enough data, so that advanced interstellar exploration may become a reality some day. However, reaching the outer solar system has its challenges as there would be a lot of problems associated with navigation, communications, power requirements, radiation shielding, life support planning as well as many other logistical problems which need to be solved before it would be possible to plan such a long range mission. This paper explores the aspect of an unmanned mission to the Heliopause which is considered as the outer boundary of the solar system along with a stopover at Pluto. The paper discusses the available nuclear technology of today in order to create a feasible mission plan to the Heliopause. Technology which is readily available today for a manned mission as well as for an unmanned mission is discussed as a case study and simulations have been used to strengthen the case. Moreover, this paper hopes to establish a precedence for an interstellar mission that can take the case study of this mission to the heliopause at least as a starting point in technological planning.

Author: UGUR GUVEN ORAL

Missions (Including Commercial)

The Utilization of Robotic Space Probes in Deep Space Missions: Case Study of Nuclear Power Requirements

The exploration of space is a driving force for mankind for understanding the universe. However, due to limitations in exploration and due to requirements for prolonged life support, it has become only possible to explore deep reaches of space through the use of robotic space probes. Through the efforts of NASA and ESA many robotic space probes have been launched to explore nearby asteroids' and comets. However, for these types of deep space missions, the robotic space probe is often far from Earth. This is a cause for many failures as the robotic probe is subjected to unknown conditions and the relapse time for communication may not be enough for the probe to react. Thus, many robotic space probes from various space agencies have been lost due to lack of communication with the probe. In addition, the amount of power that is required for deep space missions is also considerable. There should be enough power to supply the navigation systems, communication systems, propulsion systems as well as the internal heat systems in the probes. Moreover, due to the vast distances involved in the solar system, the power supply should be reliable enough for 25 to 40 years as this is the time that it will take for a robotic space probe to reach the heliopause. Hence, in order to fulfill these criteria, robotic space probes require advanced artificial intelligence protocols as well as advanced power systems to meet the long range, long duration mission requirements. Moreover, it is essential to design these systems in the most economical way possible, so that these missions can become plausible especially in light of the reduced budgets of the space programs all over the world. This paper discusses the possible solutions, as well as important challenges ahead for deep space robotic space probe missions.

SSERVI-ESF14-172

Author: BRENDAN HERMALYN

ORAL

Missions (Including Commercial)

Dust Around the Moon: Preliminary Results from the LADEE Ultraviolet Visible Spectrometer

A main scientific objective of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission is to directly measure the lunar exospheric dust environment and its spatial and temporal variability. Past studies have suggested that impacts could excavate material into a dust cloud surrounding the moon. Meteor showers, in particular, present a large number of concentrated impact events on the surface. The Ultraviolet and Visible Spectrometer (UVS), a CCD spectrograph which operates between 230 – 810 nm with a spectral resolution of <1 nm, is designed to make observations of the lunar exosphere and search for dust. Observations of the lunar limb using the UVS three-inch telescope include limb "stares" ranging from ~20 km above the surface at the terminators to ~40 km at around local noon time. At the terminators, the spacecraft can "nod" the telescope between the surface and about 50 km. Both "backward" looks (stares that point in the anti-velocity direction of the spacecraft), and "forward" looks (which flip the spacecraft to allow UVS to look in the ram direction) have been completed to permit observations in both back and forward scattering regimes. The spectra are taken at relatively high cadence (between 1 and 10 seconds each) during these observations and allow a temporally and spatially resolved view of the scatter in the exosphere. Convolution of these profiles with expected contributions from impact events can permit characterization of present day impacts on the moon. Over the course of the 140 day mission, UVS observed a dynamic and highly time-dependent dust and volatile environment on the Moon. In this study, we will present preliminary results of lunar limb observations from the Ultraviolet and Visible Spectrometer and star tracker images onboard LADEE and discuss new experiments and modeling of the contributions to the lunar dust exosphere.

Author: KYEONG KIM
ORAL

Missions (Including Commercial)

Introduction to elemental distribution of Si and other major elements on the lunar surface observed by Kaguya GRS

Gamma ray spectrometry (GRS) allows us to characterize the elemental composition of the upper tens centimeters of solid planetary surfaces. High energy resolution gamma ray data were firstly obtained by the Kaguya Gamma-Ray Spectrometer (KGRS). Elemental maps generated on the basis of the KGRS include natural radioactive elements (K, Th, U) as well as major elements maps (e.g., Ca and Al). The elemental maps of Si, Fe, and Ti were recently investigated. Analysis of the Si gamma ray has been investigated using the 4934 keV Si peak produced by the thermal neutron interaction 28Si(n,g)29Si, generated during the interaction of galactic cosmic rays and surface material containing Si. The emission rate of gamma rays is directly proportional to the abundance of Si from the lunar surface; however, it is also affected by the thermal neutron density in the lunar surface. For the correction associated with neutron effect on the Si gamma ray data, we used the relative variation in global distribution of thermal neutron flux measured by Lunar Prospector. Normalization of Si elemental abundance using the KGRS data was accomplished using Apollo returned sample data. The normalized Si elemental abundance of the KGRS data ranged from about 15 to 27% Si. The lowest and highest SiO2 abundance correspond to mineral groups like pyroxene group (PKT region) and feldspar group (Northern highlands), respectively. Our elemental map of Si derived from KGRS data shows that the highland areas of both nearside and farside of the Moon have higher abundance of Si, and the mare regions of the nearside of the Moon have the lowest Si abundance on the Moon. Our study clearly shows that there are a number of Si enriched areas compared to that of Apollo 16 site. This result is similar to the mineralogical data obtained by Diviner. The feldspathic highland areas are confirmed through the elemental map of Si by the KGRS data. When the Si map of KGRS data is compared with the LRO's mineralogical map, a reasonable agreement in understanding of the dichotomy between lunar mafic and feldspathic regions of the moon is confirmed. This presentation also includes a brief introduction to the preliminary results of Fe and Ti elemental maps obtained by KGRS. These two elements allow us to distinguish among lunar rocks, and Ti forms the basis for classifying the basalts that make up the lunar maria. Mare basalts erupting from the interior after formation of the lunar crust and filling large basins can retain important information in concert with petrologic relationships to infer the mantle compositions of the interior. Fe and Ti contents in mare regions are much higher than those in highlands. Especially high concentration of Ti on Mare Tranquillitatis is confirmed.

SSERVI-ESF14-174

Author: KURT KLAUS

ORAL

Missions (Including Commercial)

The Space Launch System and the Path to Mars

Introduction: The Space Launch System (SLS) is the most powerful rocket ever built and provides a critical heavy-lift launch capability. Enhanced capabilities enable missions including human exploration, planetary science, astrophysics, heliophysics, planetary defense and commercial space exploration. We will focus on mission concepts relevant to the Global Exploration Roadmap (GER) and the Solar System Exploration Research Virtual Institute (SSERVI) mission.Asteroid Redirect Mission (ARM): Bill Gerstenmaier at the NASA Lunar Science Institute (NLSI) meeting in July 2013 referred to the ARM in part as a mission to the lunar vicinity. The ARM mission requirements result in system design based on a modified version of our 702 spacecraft product line. Including a NASA Docking System (NDS) on the Asteroid Redirect Vehicle allows for easier crewed exploration mission integration and execution.Asteroid Exploration Module: Crew operations at a redirected asteroid could be significantly enhanced by providing additional systems and EVA capabilities beyond those available from Orion only missions. An Asteroid Exploration Module (AEM) located with the asteroid would improve the science and technical return of the asteroid mission while also increasing Orion capability through resource provision and providing an abort location and safe haven for vehicle contingencies.Cislunar Exploration Platform: The AEM could be repurposed as a cislunar exploration platform that advances scientific research, enables lunar surface exploration and provides a deep space vehicle assembly and servicing site. The Exploration Platform provides a flexible basis for future exploration, since it reduces cost through reuse of expensive vehicles and reduces the number of launches needed to accomplish missions. International Space Station (ISS) industry partners have been working for the past several years on concepts for using ISS development methods and residual assets to support a broad range of exploration missions. These concepts have matured along with planning details for NASA's SLS and Multi-Purpose Crew Vehicle (MPCV) to allow serious consideration for a platform located in the Earth-Moon Libration (EML) system.Lunar Surface: The mission objectives are to provide lunar surface access for crew and cargo and to provide as much system reuse as possible. Subsequent missions to the surface can reuse the same lander and Lunar Transfer Vehicle.Mars Vicinity: The International space community has declared that our unified long term goal is for a human mission to Mars but major work remains to define how it will be done. Translunar infrastructure and heavy lift capability are key to this approach. Recent analysis has suggested that a habitat-based gateway in translunar space would be helpful as an assembly node for Mars and for many other missions. The moons of Mars would provide an excellent stepping stone to the surface. As a "shake-down" cruise before landing, a mission to Deimos or Phobos would test all of the systems except those needed to get to the surface and back. This test would provide confidence for the in-space transportations and crew habitat systems.

Author: EMILY LAW

ORAL

Missions (Including Commercial)

The Lunar Mapping and Modeling Portal: Tools for Mission Planning, Science, and Outreach

The Lunar Mapping and Modeling Portal (LMMP) provides a web-based Portal and a suite of interactive visualization and analysis tools enabling mission planners, lunar scientists, and engineers to access mapped lunar data products from past and current lunar missions. While emphasizing mission planning, LMMP also addresses the lunar science community, the lunar commercial community, education and public outreach (E/PO), and anyone else interested in accessing or utilizing lunar data. Its visualization and analysis tools allow users to perform analysis such as lighting and local hazard assessments including slope, surface roughness and crater/boulder distribution. Originally designed as a mission planning tool for the Constellation Program, LMMP has grown into a generalized suite of tools facilitating a wide range of activities including the planning, design, development, test and operations associated with lunar sortie missions; robotic (and potentially crewed) operations on the surface; planning tasks in the areas of landing site evaluation and selection; design and placement of landers and other stationary assets; design of rovers and other mobile assets; developing terrain-relative navigation (TRN) capabilities; deorbit/impact site visualization; and assessment and planning of science traverses. Significant advantages are afforded by LMMP's features facilitating collaboration among members of distributed teams (e.g., mission planning team, mission proposal team). Team members can share visualizations and add new data to be shared either with the entire LMMP community or only with members of their own team. Sharing of multi-layered visualizations is made easy with the ability to create and distribute LMMP's digital bookmarks. LMMP fosters outreach, education, and exploration of the Moon by educators, students, amateur astronomers, and the general public. These efforts are enhanced by Moon Tours, LMMP's mobile application, which makes LMMP's information accessible to people of all ages, putting opportunities for real lunar exploration in the palms of their hands. Moon Tours allows users to browse and search LMMP's entire catalog of over 600 data imagery products ranging from global basemaps to LRO's Narrow Angle Camera (NAC) images providing details of down to .5 meters/pixel. Users are able to view map metadata (e.g., abstract of the data) and can zoom in and out of the map to view more or less data, as well as pan around the entire lunar surface with the appropriate basemap. They can arbitrarily stack the maps and images on top of each other, showing layered views of the surface with layer transparency adjusted to suit the user's desired look. They can even view lunar terrain data rendered in realtime 3D, and calculate distances between locations on the lunar surface. While great utility is provided by LMMP's interface and tools, it also provides particular value through its ability to serve data to a variety of other applications. In the outreach realm, this has been demonstrated with data served to planetariums and NASA's Eyes on the Solar System. This presentation will provide an overview of LMMP Uses and capabilities, highlight new features, and preview coming enhancements. It will supplement and enhance the LMMP demonstration that will be hosted at the Forum..

SSERVI-ESF14-176
Author: JOSEPH LAZIO
ORAL

Missions (Including Commercial)

Fifty Years of Exploration Science with the Deep Space Network

Established on 1963 December 24, the Deep Space Network (DSN) has played an integral role in science and exploration from the beginnings of the space program. Receiving the data from the robotic Ranger spacecraft, the DSN helped provide the first high resolution images of the surface of the Moon, the first human exploration target. During the Apollo program, the DSN downlinked both a wealth of scientific data and provided the critial communications with the astronauts. Later, the Goldstone radar observations helped provide early indications of water in the lunar polar regions, an observation subsequently confirmed by the LCROSS mission.Today, the DSN continues the tradition of providing science measurements and advanced reconnaissance for robotic and human missions. Radio science links between spacecraft and the DSN are used to probe the atmospheres, gravity fields, and interior structures of bodies, and the Goldstone radar system is used to measure the rotation rates, sizes, shapes, surface features, and precision orbits for asteroids. Highlights of the precision of radio science measurements include recent results from Mars Express-DSN links and the GRAIL mission. During recent Mars Express close fly-bys of Phobos, radio science measurements on the Mars Express-DSN link indicate that the interior of Phobos is highly porous and suggesting that this Martian satellite re-accreted in place. The GRAIL mission used both spacecraft-spacecraft and spacecraft-DSN links to provide an unparalled gravity field and near sub-surface structure map of the Moon. Highlights of Goldstone radar observations include the asteroid (101955) Bennu, which is the target of the forthcoming OSIRIS-REx mission, and imaging and precision orbit determination of the close-approaching asteroids 99942 Apophis and 2012 DA14.Looking toward the future, the existing suite of science measurement techniques both will continue and is likely to expand with higher resolution radar imaging and the inclusion of laser communications. In addition to even higher precision link science to spacecraft for probing interior structures, the laser communication infrastructure is likely to allow ``opportunistic” use of laser ranging to the Moon and other bodies in the inner solar system.Part of this research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics & Space Administration.

Author: PASCAL LEE

POSTER

Missions (Including Commercial)

Phobos And Deimos & Mars Environment (PADME): A Proposed Discovery Mission

Ever the since their discovery in 1877 by American astronomer Asaph Hall, the two moons of Mars, Phobos and Deimos, have been mysteries. Spacecraft missions have revealed that they are irregular-shaped small bodies with a long collisional history and complex geology, but their origin remains unknown. Three very different hypotheses have been proposed for their origin: 1) They are captured asteroids, possibly primitive D-type asteroids from the outer part of the main asteroid belt; 2) They are remnants of Mars's own formation; 3) They are reaccreted impact ejecta from Mars. Superimposed on these hypotheses is another unresolved hypothesis: 4) Phobos and Deimos were once part of a single larger object. There are also two intriguing hypotheses concerning the present evolution of Phobos and Deimos: 5) A faint dust cloud fed by micrometeoroid impacts exists in steady-state in the immediate vicinity of Phobos and Deimos; 6) A faint dust ring and a faint dust torus occur at the location of Phobos and Deimos's orbits, respectively. Each one of these hypotheses has radically different implications regarding the evolution of the solar system, and/or the origin and evolution of its planets, satellites, and/or rings. These hypotheses are best tested or at least constrained by simultaneously investigating the internal structure and bulk composition of Phobos and Deimos, and the abundance and distribution of dust in their vicinity. The Phobos And Deimos & Mars Environment (PADME) mission is a proposed new NASA Discovery mission that would test the above hypotheses by investigating simultaneously the internal structure and bulk composition of Phobos and Deimos, and the abundance and distribution of dust in Mars orbit. The PADME mission would use the proven LADEE spacecraft bus, radio science, and a suite of highly mature instruments to achieve its science objectives. PADME would launch in 2020 and reach Mars orbit in early 2021. It would then begin a series of slow and increasingly close flybys of Phobos to carry out the following baseline observations in unprecedented detail: a) measure the small body's gravity field, b) image its position, orientation, shape, and surface features; c) measure the bulk composition of the regolith; d) measure the abundance and distribution of dust in its vicinity. The same series of observations would then be performed at Deimos. PADME would offer a low-cost and low risk giant leap in our knowledge about the evolution of the solar system and the origin and evolution of small bodies, of small planetary satellites, of planetary rings, and of Phobos and Deimos specifically. PADME would also fill key strategic knowledge gaps identified by NASA's HEOMD in advance of planning human missions to Phobos and/or Deimos. PADME would be built, managed, and operated by NASA Ames Research Center. Partners include the SETI Institute, NASA JPL, NASA KSC, University of Colorado, University of Maryland, Cornell University, Royal Observatory of Belgium, JAXA, and others.

Author: MARCUS MURBACH

ORAL

Missions (Including Commercial)

Atromos: A Cubesat-Derived Mission for the Exploration of the Martian System Using M-PODs

A companion mission is proposed that could provide an enhanced capability of exploring scientifically provocative sites on the surface of Mars and related moons. Options are discussed for a 'companion' mission which could be deployed from the cruise-stage of larger dedicated Mars missions. While the precedence is the DS-2 mission attempted in 1998, the intent would be to 'soft' land payloads on the surface of the planet or moons. In the same fashion that the compartmentalization of the risk is now routinely done for Low Earth Orbit (LEO) satellites, an M-POD (Mars PicoSat Orbital Deployer) is proposed at a larger scale that would have an analogous function. For the planetary surface area targets, an Entry/Descent/Landing (EDL) technology is uniquely described that permits the deployment of such missions from the M-POD. For Phobos, a propulsion system is similarly described. Given the current interest in interplanetary nano-satellites, the Mars system is particularly attractive in part due to the COM infrastructure that already exists – and thus makes such an undertaking credible. This 'companion' mission capability is shown to dramatically enhance the scientific benefit at low cost and risk.

SSERVI-ESF14-179

Author: SCOTT MURCHIE

ORAL

Missions (Including Commercial)

MERLIN: A Science and Exploration Mission to the Moons of Mars

Mars' moons Phobos and Deimos are low-albedo, D-type bodies. Their compositions have been interpreted as highly space-weathered material like that forming bulk Mars or Mars's crust, or alternatively primitive carbonaceous material, possibly sampling material that contributed organics and volatiles to the accreting terrestrial planets. The moons' origins, as well as their potential for in situ resources for future explorers, depend on their composition. A composition related to that of Mars would indicate an origin within the Mars system, yet offer minimal C and H for future explorers; a primitive carbonaceous composition would imply formation in more distant parts of the solar system, possibly related to Trojan asteroids, any may provide significant in situ resources. A Discovery-class mission concept, the Mars-Moon Exploration, Reconnaissance and Landed Investigation (MERLIN), will use in situ compositional measurements to test models for the moon's origin [1]. The nominal landing target is Phobos. The scientific measurement objectives of MERLIN are to determine Phobos' elemental and mineralogical composition, to investigate its volatile and organic content, to characterize processes that have modified its surface, and to determine how it is related to Deimos and other solar system bodies. These same measurements characterize physical properties of the surface and the moon's environment, providing valuable precursor information preparatory to future human exploration. To achieve MERLIN's objectives, a landed payload will obtain stereo imaging and measurements of elemental and mineralogical composition and interior structure. An orbital payload will acquire global high-resolution and color imaging, putting the landing site in context, and characterize the radiation and particle environments near both moons. Following MOI the spacecraft spends several months in elliptical orbits to characterize the moons' "dust belts" and performs multiple close flybys of Deimos to acquire near-global imaging and a refined density estimate. It then performs a rendezvous with Phobos, using small changes in the spacecraft's orbit around Mars to investigate Phobos from a range of altitudes and illuminations. Data taken during 1- to 2- km altitude flyovers will certify a landing site. The spacecraft will be delivered to a point several km above the surface, and will navigate to landing on one of Phobos' two distinct spectral units. A 90-day baseline landed operations period will provide a complete set of landed measurements. A science enhancement option includes ascent and relanding to perform in situ study of the second distinct spectral unit.References: [1] Murchie, S. et al. (2012) MERLIN: Mars-Moon Exploration, Reconnaissance and Landed Investigation, Global Conference on Space Exploration, paper GLEX-2012.03.2.1x12281, Washington, D.C., May 2012.

SSERVI-ESF14-180
Author: CHARLES RADLEY
ORAL

Missions (Including Commercial)

CTIPS - (CisLunar Tether Deployment, Physics and Survivability)

Very long tethers in space (thousands of kilometers) offer interesting and useful applications. However, to date no tethers approaching this length have been attempted in space. There are numerous questions about how such tethers could be deployed and how they might behave during and after deployment.Tether deployment near Earth is subject to high tidal forces, which become especially significant with longer tethers. Furthermore, unless the orbit is perfectly circular, tidal forces will vary greatly. This introduces non-deterministic disturbances into the system, which complicate the design and could result in unstable systems. Therefore, prior to attempting long tether deployments near Earth it is beneficial to perform such tests at some distance away from Earth in a stable environment with low, non-varying tidal forces.One of the more convenient types of locations near to Earth which have low and nearly constant tidal forces is the Earth-Moon Lagrange 1 Point. (EML1) LiftPort Group proposes a mission concept called CTIPS - (CisLunar Tether Deployment, Physics and Survivability) experiment to investigate behavior of long tethers during and after deployment, at EML1. This testing is essential for developing technology to deploy planetary and lunar elevators, as well as long tethers for other applications.

SSERVI-ESF14-181

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

From ODEs to PDEs : Simulating and Managing the Behavior of Lunar Space Elevators

A Lunar Space Elevator (LSE) would be by many orders of magnitude the largest structures ever built and deployed by our civilization, with an expected tether length of well over 250,000 km. Even preliminary tethers deployed in CisLunar space, either for engineering tests or for Lunar sample return or for other scientific purposes, would likely exceed the diameter of the Earth in length and thus be the biggest mechanical structures ever created. Such “CisLunar” tethers will present novel problems of simulation, monitoring and control. Unlike conventional problems in orbital dynamics, which can be described by Ordinary Differential Equations (ODEs), the dynamics of CisLunar tethers will requiring modeling by Partial Differential Equations (ODEs). Mathematically the modeling of CisLunar tethers will have similarities to both Numerical Weather Forecasting (NWF) and the numerical modeling of large structures, such as bridges. CisLunar tethers will support a variety of oscillations and normal modes, excited by both gravitational perturbations and the motion of cargo vehicles along the tether, that are unlikely to be fully observed by any monitoring system; the techniques developed for NWF data assimilation are thus likely to be essential for the high capacity usage of an operational LSE. This presentation will describe the mathematical basis for CisLunar tether monitoring and operations and the current status of tether simulations.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Lunar Elevator - Partial Deployment during Translunar cruise

It is rather difficult to deploy a lunar elevator initially from the Earth-moon L1 Lagrange location because the tidal forces are very small. So the two ends of the tether could drift in quasi-random fashion and become uncontrollable and tangled. They will need to reach a length of several thousands kilometers before they become gravity gradient stabilized. The question of how to achieve such a deployment in the absence of tidal forces is difficult.So we consider deployment of a few thousand kilometers before reaching the L1 location.The partial deployment could begin shortly after the Trans-lunar Injection burn. Two options for initial deployment are: 1) Springs and/or small rockets can be used to fire out the two ends of the tether, this will impart initial separation velocity 2) spin up the spacecraft and then release the ends of the tether and deployment begins via centrifugal force. Over a few days the three objects (hub and two tether ends) will tend to drift apart since they are in different orbits, and this will introduce useful tension on the tether. This quasi-tidal force will maintain tension during the cruise. We plan to use electric propulsion which will slowly raise the perigee until the tether craft rendezvous at EML1. As for electric propulsion, it is probably not necessary to have electric thrusters on all three objects, perhaps only on the central object, and the two others will remain attached via the tethers During this time the tidal tension will reduce. Prior to this, it might make sense to spin up the system, maybe to one or two revs per hour, to keep it under controlled attitude and tension. Once at EML1, the system will be de-spun and the tether aligned on the Earth-Moon axis and achieve gravity gradient stabilization. Then it can be deployed to its full length.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Commercial Mining with a Lunar Elevator

The Earth's Moon is a treasure trove of mineral resources, such as precious metals, rare earth elements, Helium-3 and Oxygen for propellants. However, the cost of soft landing on the Moon is currently very high. Using modern fibers we can build a lunar elevator which reduces the cost of lunar landing sixfold.The lunar elevator concept is a long tether which is loaded under tension by terrestrial and lunar gravity. One end is anchored on the Moon and the other end free, hanging towards Earth. The orbital center of mass of the system is located at Earth-Moon Lagrange one location (EML1) approximately 50,000 kilometers from the lunar surface. The near-side L1 tether is attached to the lunar equator at Sinus Medii. Such a tether can now be built inexpensively from commercially available materials.For a one time capital cost of US$800Million [2012], a lunar elevator can be built today using existing available materials. This first generation lunar elevator will softly deliver an infinite number of payloads to the lunar surface, each weighing 100 kg, and retrieve the same amount of material from the lunar surface. The alternative of using chemical rockets to soft land on the Moon [or return material] is prohibitively expensive. The lunar elevator eliminates the delta-vee advantage of near Earth asteroids. Everything you find in asteroids is available in lunar regolith at somewhat lower concentrations.Helium-3 today sells for a million dollars per ounce on the secondary market, demand far exceeds supply. It is abundant on the Moon but rare on Earth. US supplies are rationed by the White House and will be exhausted by 2030. Lunar rocks [meteorites] today sell for about $200,000 per kg.Rare Earth Elements (REEs) are vital to defense and high technology industries, today 96% of REEs come from China-controlled assets. There are few alternative mining sites, but the Moon is one.Use of lunar oxygen would reduce the cost of geosynchronous spacecraft launch by about 7 times.A lunar elevator can return lunar material to Earth or LEO at a low enough cost that prices of certain commodities will generate sufficient revenues to amortize the capital cost over reasonable period of time.and then operate the system at a net profit. The lunar elevator could reduce the cost of lunar mining of such commodities to a par with terrestrial mining.

Author: CHARLES RADLEY
ORAL

Missions (Including Commercial)

Ceres soft landing and sample return using synchronous tether elevator

The dwarf planet Ceres is a high priority target for exploration due to recent confirmation of escaping water plumes. A substantial percentage of the body is now believed to be composed of water. Ceres has a mass about 1/10th of Earth's Moon and rotates about every nine hours. The altitude of a synchronous circular orbit about Ceres is therefore at an altitude of about a few thousand kilometers above Ceres' equator. A tether or space elevator centered by mass on that altitude can be inexpensively constructed from one of a variety of commercially available polymer materials. It would extend in two directions from the synchronous orbit; firstly downwards to the surface of Ceres, and secondly upwards away from the synchronous orbit to a counterweight.The surface end need not be attached to the body, and indeed the elevator COM altitude could be slightly below the synchronous altitude, so the system would tend to slowly drift around the equator of Ceres. This system can thus cruise around the Ceres equator, and collect samples from the entire circumference. It can also soft-land multiple sensors and rovers around the equatorial band of Ceres. The synchronous tether cannot access the higher latitudes, but that might be possible by a rotating tether in a polar orbit, which would transfers samples (or equipment) between the equator and the higher latitudes. However the rotation rate of Ceres is high enough that a polar orbiting tether might have difficulty to rendezvous with objects on the surface due to the transverse motion of the surface relative to the tether tip. To soft land payloads from the polar tether would also require cancellation of the transverse surface velocity component.It is possible that a polar orbit around Ceres would be disturbed by its non-uniform gravitational field, and by Jupiter and the Sun. Therefore, station-keeping is probably required, and this could be done efficiently with a solar-powered electric thruster. It might therefore be attractive to maintain the spacecraft in an orbit which is orthogonal to the Sun so it is in continuous sunlight, and the solar arrays constantly illuminated. This type of orbit is known as a dawn-dusk orbit.

SSERVI-ESF14-185
Author: CHARLES RADLEY
ORAL

Missions (Including Commercial)

A Roadmap for the Development of the Lunar Space Elevator

A Lunar Space Elevator (LSE) could be constructed with existing materials, considerably accelerating the exploration and economic development of the solar system. The LSE would be an extremely long tether extending from the Lunar Surface, through the Earth-Moon L1 Lagrange point (EML 1) and into CisLunar space. Requiring a relatively modest capital investment, as compared to chemical rockets, the LSE will reduce the cost of lunar soft landing sixfold and cost of lunar sample return is by about one thousand times. For soft landing the LSE would thus pay for itself in 20 payload cycles; for sample return - in a single payload cycle. The LiftPort Group Lunar Space Elevator Development plan includes an initial tether test in CisLunar space, CTIPS (CisLunar Tether Deployment, Physics and Survivability), followed by a rotating tether Lunar sample return mission or missions, ROTSAR (ROtating Tether SAmple Return) and the Lunar Space Elevator Infrastructure (LSEI). The LSEI prototype, requiring launch of a single heavy lift vehicle, would be able to return roughly 1 ton of lunar samples per year, and deploy a similar quantity of equipment onto the Lunar surface. This presentation will describe the various components of LiftPort's Development plan, how it will lead to an operational LSEI, and its implications for the economic development of the Moon.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

CTIPS - (CisLunar Tether Deployment, Physics and Survivability)

Very long tethers in space (thousands of kilometres) offer some interesting and useful applications. However, to date no tethers approaching this length have been attempted in space. There are numerous questions about how such tethers could be deployed and how they might behave during and after deployment.Tether deployment near Earth is subject to high tidal forces, which become especially significant with longer tethers. Furthermore, unless the orbit is perfectly circular tidal forces will vary greatly, which will introduce non-deterministic disturbances into the system, which complicate the design and could result in unstable systems. Therefore, prior to attempting long tether deployments near Earth it could be beneficial to perform such tests at some distance away from Earth in a stable environment with low non-varying tidal forces.One of the more convenient types of locations near to Earth which have low and nearly constant tidal forces are the Earth-Moon lagrange locations. (EMLs) LiftPort Group proposes a mission concept called CTIPS - (CisLunar Tether Deployment, Physics and Survivability) experiment to investigate behavior of long tethers during and after deployment, at an EML location. This testing will be essential for developing technology to deploy planetary and lunar elevators, as well as long tethers for other applications.

Author: CHARLES RADLEY
ORAL

Missions (Including Commercial)

Lunar Elevator - Partial Deployment during Translunar cruise

It is rather difficult to deploy a lunar elevator initially from the Earth-moon L1 Lagrange location because the tidal forces are very small. So the two ends of the tether could drift in quasi-random fashion and become uncontrollable and even tangled they will need to reach a length of several thousands kilometres before they become gravity gradient stabilized, and the question how to achieve such a deployment in the absence of tidal forces is difficult..So we consider deployment by a few thousand kilometers before reaching the L1 location.The partial deployment could begin shortly after the Trans-lunar Injection burn. Two options for initial deployment are: 1) Springs and/or small rockets can be used to fire out the two ends of the tether, this will impart initial separation velocity 2) spin up the spacecraft then release the ends of the tether and deployment begins via centrifugal force. Over a few days the three objects (hub and two tether ends) will tend to drift apart since they are in different orbits, and this will introduce useful tension on the tether. This quasi-tidal force will maintain tension during the cruise. We plan to use electric propulsion which will slowly raise the perigee until the tether craft rendezvous at EML1/2. As for electric propulsion, it is probably not necessary to have electric thrusters n all three objects, perhaps only on the central object, and the two others will remain attached via the tethers During this time the tidal tension will reduce. Prior to this, it might make sense to spin up the system, maybe to one or two revs per hour, to keep it under controlled attitude and tension. Once at EML1/2 the system will be de-spun and the tether aligned on the Earth-Moon axis and achieve gravity gradient stabilization. Then it can be deployed to its full length.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Commercial Mining with a Lunar Elevator

The Earth's Moon is a treasure trove of mineral resources, such as precious metals, rare earth elements, Helium-3 and Oxygen for propellants. However, the cost of soft landing on the Moon is currently very high. Using modern fibers we can build a lunar elevator which reduces the cost of lunar landing sixfold. Furthermore, the cost of lunar sample return is reduced by about one thousand times versus chemical rockets. For soft landing payloads, the LSE pays for itself in 20 payload cycles; for sample return it can pay for itself in as little as a single payload cycle, depending on the sample site.The lunar elevator concept is a long tether which is loaded under tension by terrestrial and lunar gravity. One end is anchored on the Moon and the other end free, hanging towards Earth. The orbital center of mass of the system is located at an Earth-Moon Lagrange location, either L1 or L2, approximately 50,000 kilometres from the lunar surface. Such a tether can now be built inexpensively from commercially available materials, e.g. Zylon, Dyneema, M5.The near-side L1 tether is attached to the lunar equator at Sinus Medii. For a one time capital cost of US$800Million [2012], a lunar elevator can be built today using existing available materials. This first generation lunar elevator will softly deliver an infinite number of payloads to the lunar surface, each weighing 100 kg, and retrieve the same amount of material from the lunar surface. The alternative of using chemical rockets to soft land on the Moon [or return material] is prohibitively expensive.A lunar elevator is far cheaper than the electromagnetic mass drivers proposed by Gerard O'Neil, but back in his time the tether materials were not strong enough, today they are. The lunar elevator eliminates the delta-vee advantage of near Earth asteroids. Everything you find in asteroids is available in lunar regolith at somewhat lower concentrations.Helium-3 today sells for a million dollars per ounce on the secondary market, demand far exceeds supply. It is abundant on the Moon but rare on Earth. US supplies are rationed by the White House and will be exhausted by 2030. This is nothing to do with nuclear fusion energy. Lunar rocks [meteorites] today sell for about $200,000 per kg.Rare Earth Elements (REEs) are vital to defense and high technology industries, today 96% of REEs come from China, there are few alternatives but the Moon is one.Use of lunar oxygen would reduce the cost of geosynchronous spacecraft launch by about 7 times.A lunar elevator can return lunar material to Earth or LEO at a low enough cost that prices of certain commodities will generate sufficient revenues to amortize the capital cost over reasonable period of time.and then operate the system at a net profit. The lunar elevator could reduce the cost of lunar mining of such commodities to a par with terrestrial mining.

SSERVI-ESF14-189

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Ceres soft landing and sample return using synchronous tether elevator

The dwarf planet Ceres is a high priority target for exploration due to recent confirmation of escaping water plumes. A substantial percentage of the body is now believed to be composed of water. Ceres has a mass about 1/10th of Earth's Moon and rotates slightly slower than once every nine hours. The altitude of a synchronous circular orbit about Ceres is therefore at an altitude of about a few thousand kilometres above Ceres' equator. A tether or space elevator centered by mass on that altitude can be cheaply built from one of a variety of several commercially available polymer materials. It would extend in two directions from the synchronous orbit; firstly downwards to the surface of Ceres, and secondly upwards away from the synchronous orbit to a counterweight. The surface end need not be attached to the body, and indeed the elevator COM altitude could be slightly below the synchronous altitude, so the system would tend to slowly drift around the equator of Ceres. This system can thus cruise around the Ceres equator, and collect samples from the entire circumference. It can also soft-land land multiple sensors and rovers around the equatorial band of Ceres. The synchronous tether cannot access the higher latitudes, but that might be possible by a rotating tether in a polar orbit, which would transfers samples (or equipment) between the equator and the higher latitudes. However the rotation rate of Ceres is high enough that a polar orbiting tether might have difficulty to rendezvous with objects on the surface due to the transverse motion of the surface relative to the tether tip. To soft land payloads from the polar tether would also require cancellation of the transverse surface velocity component.It is possible that a polar orbit around Ceres would be disturbed by its non-uniform gravitational field, and by Jupiter and the Sun. Therefore, stationkeeping is probably required, and this could be done efficiently with a solar-powered electric thruster. It might therefore be attractive to maintain the spacecraft in an orbit which is orthogonal to the Sun so it is in continuous sunlight, and the solar arrays constantly illuminated. This type of orbit is known as a dawn-dusk orbit.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Rotating tethers in lunar polar orbit for sample return

Rotating tether Lunar sample return mission or missions, ROTSAR (ROtating Tether SAmple Return)A lunar orbiting tether with weights at each end rotates such that the tether is always in the orbital plane, and the axis of its rotation is orthogonal to the orbital plane.The speed of the tether tip equals the orbital speed, the lower tip velocity vector is opposed to the orbital velocity vector, so it is like a wheel rolling along the lunar surface, i.e. the speed of the tether tip, when at the lunar surface, will be near zero relative to the Earth-Moon inertial frame . For a tether in polar orbit around the Moon, the rotation of the Moon about its axis is slow [~= 17 cm/s] so would not introduce significant transverse forces on the tether tip at the lunar surface. Since lunar rotation is the largest residual relative motion [between the tether tip and the lunar surface] it is practical for the tether tip to rendezvous with and attach to objects on the lunar surface. It is also practical for the tether to release payloads which soft land on the lunar surface with small and acceptable horizontal velocity.Payloads can be soft landed on (or collected from) different latitudes on the lunar surface. In particular we would use the equatorial zero longitude and the antipodal 180 degrees lunar longitude points as depot sites, since they can be accessed by a stationary lunar elevator, for further transport to/from Earth or cislunar trajectories.Polar lunar orbits are significantly disturbed by the Earth's gravity, therefore frequent station-keeping burns will be needed to extend the life of the system beyond a few months. Electric propulsion would be an efficient option. The orbit could be maintained in a plane orthogonal to the Sun so it is in continuous sunlight, maximizing solar energy to power the electric thruster. This is known as a dawn-dusk orbit type.Over the course of a lunar sidereal month a polar orbiting ROTSAR would overfly the entire range of lunar longitudes. Depending on the phasing of the spacecraft around the lunar orbit, it could access any point on the lunar surface. For a typical orbital period of 3 hours, there would be approximately 120 orbits per month. The distance between each successive swath of each orbital pass at the lunar equator would be about 100 kilometres depending on the precise orbital period. To increase the frequency with which each point on the lunar surface could be accessed, multiple ROTSARs could be deployed, separated from each other around the polar sun-synchronous [dawn-dusk] orbit. A ROTSAR acting in conjunction with a stationary lunar elevator can establish a two-way supply chain between the Earth and any point on the lunar surface, accommodating delicate payloads, e.g humans. It can also collect samples from any point on the lunar surface, and deposit them near the base of the lunar elevator for return to Earth.

SSERVI-ESF14-191

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Lunar Elevator - Payload transfer on Earthbound flow

The weight of the heat shield for Earth atmosphere entry is rather heavy, but such hardware is needed for lunar sample return. However, it is inefficient and expensive to soft land this equipment on to the lunar surface. It would be more efficient to store the heat shield at the Earth-Moon L1 lagrange location.This can be done in conjunction with a lunar elevator tether system. Samples from the lunar surface are collected via a lunar elevator. The tether climber leaves the lunar surface and moves earthwards reaching a cruise speed of about 700 m/sc. In order to maintain maximum payload throughput over time we need to maintain the velocity and not slow down. The climber needs to rendezvous and connect with the heat shield with a smaller closing velocity to avoid damage or destruction. Hence we must start the heat shield moving earthwards at a few hundred metres per second, with a small enough velocity that the climber can catch up with it in a reasonable time, but large enough to avoid destructive impact.We will need to analyze various velocity profile of the heat shield module, and the starting time of the acceleration.The collision between the climber and the heat shield is softened by shock absorbers and the payload is then connected to the heat shield by latches. The climber then separates from the payload and decelerates to a stop. The heat shield with payload are released from the tether and fall ballistically to Earth where they enter the atmosphere and are recovered.The climber returns to the EML1 location (or other point along the tether) where it is loaded with a new payload which it then transports to the lunar surface.This cycle is then repeated an arbitrary number of times.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Mars landing and sample return using Phobos based elevator

We analyze how much delta-vee saving we can gain for Mars landing and Mars surface launch using Phobos elevator.The lower end [tip] of the Phobos elevator hangs in Mars' atmosphere moving at ~500 metres per second, this is much less than orbital velocity at that altitude. For an object sitting on the Mars surface, a small sub-orbital burn will allow the Mars lander to take-off and rendezvous with the tip of the Phobos tether. A cheaper method is for an aircraft to take off from a runway and fly up to the tether end point and rendezvous at a reasonable altitude within the aircraft operational ceiling. The tether tip can potentially also touch the Mars surface from time to time according to a profile taking advantage of the eccentricity of Phobos orbit and the topography of the martian terrain.For a single mission, the delta-vee to reach Phobos with a tether will be rather high. However, we must calculate the savings in cost for Mars take-off and landing, and then clculate how many Mars lander missions would result in a delta-vee saving wich exceeds the delta-vee cost of establishing the tether on Phobos.Drag Force = 1/2 rho v^2 C_D Av = 533 m / sec. The speed of sound on Mars (surface std atmosphere, 6 millibars pressure) is 244 m/sec, so this is Mach 2.2rho_ surface = 0.02 kg / m^3let us assume a 20 ton body with a projected radius = 1 meter, so that A = pi meter^2From looking at various tables (include R.H. Goddards) C_D ~ 0.3 is reasonable for a "well designed" body at mach 2.2Drag = 2700 Newtons (and power dissipated = 1.4 MW)Gravity force on this body = 73000 NewtonsDrag / Gravity ~ 4%So we can "fly" this inside of Mars's atmosphere. Now, note that the Phobos orbit eccentricity e = 0.0151 and a = 9378 km, so ae (the deviation from the mean) is 141 km. So, the tip could be at 141 km average altitude and dip down to the surface once per orbit, and up to 282 km once per orbit, BUT, Pavonis Mons is on the equator, and it has an elevation of 14 km, so it has to be taken into account. Let us consider the rotation of Mars and the orbit of Phobos. Let a "day" be a std solar day, of 86,400 TAI seconds, and let all times be as seen from the Earth3 sidereal orbits of Phobos are 0.95673 days, or 0.932527 Mars sidereal days. 13 sidereal orbits of Phobos are 4.14583 days, or 4.04095 Mars sidereal days, which is a much better quasi-resonance. Once every 4 days the active end of the tether would become aerodynamically active and "fly" to the pickup / dropoff point (whether that is on Pavonis Mons or just on the Tharsis ridge).

Author: CHARLES RADLEY
ORAL

Missions (Including Commercial)

Minimalist lunar Helium-3 mining machine

There is considerable commercial potential for Helium-3 mining on the Moon. No one has built a working nuclear fusion reactor, yet there is much discussion of lunar Helium-3 (3He) isotope as nuclear fuel. Alas, the fusion market simply does not exist – and will not in a predictable timeframe. The fusion discussion has distracted the community from the market which already exists for 3He; a market which can be profitably supplied from the Moon more cheaply than from terrestrial sources. Surprisingly, since 2001 a strong new market has rapidly emerged. 3He is in great demand since the 9/11 attacks. New demand has been driven by the US Department of Homeland Security, which needs 3He for neutron detectors at all seaports, airports and borders, to scan for nuclear material. Demand also increased from the medical sector (MRIs), and for natural gas exploration. There is increasing demand from the oil and gas exploration sector from wireline well logging companies, and they currently receive top priority by the White House allocation committee. The US 3He stockpile came from the decay of nuclear warheads; it is dwindling rapidly. In 2008 the White House imposed 3He rationing to eke out remaining reserves and supply fell from 80,000 to 14,000 liters per year. Projected demand for 3He implies that U.S. production alone cannot meet anticipated worldwide demand.. Global demand is now over 60,000 liters per year, and the price shot up from $100/l in 2008 to $2,000/l in 2009. The price continues to increase.. Current White House projections are that national He3 supplies will be completely depleted some time between 2025 and 2035. Supplies from Russia and Canada will not meet global demand.LiftPort is planning a proof of concept of a minimalist lunar helium-3 mining robot, approx 100 kg, based on the designs of the University of Wisconsin Fusion Technology Institute.There will be opportunities for NASA science instruments to fly on LiftPort provided infrastructure to the lunar surface. As a by-product of Helium-3 mining, a large quantity of many other volatile gases will be produced all of which will be of benefit to NASA operations in the lunar vicinity, such as: water, carbon monoxide, carbon dioxide, and methane. These gases can be used for rocket propellant and to feed fuel cells to produce energy during the lunar night.The Helium-3 mining machine would be an apparatus mounted on a rover machine bus developed by one of the Google Lunar Xprize teams, there are several to choose from. The machine will be delivered to cislunar space via the NASA SLS. and will soft land on the lunar surface. The system will be solar powered and will heat the regolith to liberate volatile gases. Fractional distillation will separate the Helium from the other constituent gases; then a superleak isotope enrichment process will separate the Helium-3 from the Helium-4.

SSERVI-ESF14-194

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

A Roadmap for the Development of the Lunar Space Elevator

A Lunar Space Elevator (LSE) could be constructed with existing materials, considerably accelerating the exploration and economic development of the solar system. The LSE would be an extremely long tether extending from the Lunar Surface, through the Earth-Moon L1 Lagrange point (EML 1) and into CisLunar space. Requiring a relatively modest capital investment, the LSE will reduce the cost of lunar soft landing sixfold and cost of lunar sample return is by about one thousand times, as compared to chemical rockets. For soft landing the LSE would thus pay for itself in 20 payload cycles, for sample return in a single payload cycle. The LiftPort Group Lunar Space Elevator Development plan includes an initial tether test in CisLunar space, CTIPS (CisLunar Tether Deployment, Physics and Survivability), followed by a rotating tether Lunar sample return mission or missions, ROTSAR (ROtating Tether SAmple Return) and the Lunar Space Elevator Infrastructure (LSEI). The LSEI prototype, requiring one launch of a heavy lift vehicle, would be able to return roughly 1 ton of lunar samples per year, and deploy a similar quantity of equipment onto the Lunar surface. This presentation will describe the various components of LiftPort's Development plan, how it will lead to an operational LSEI, and its implications for the economic development of the Moon.

SSERVI-ESF14-195

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

From ODEs to PDEs : Simulating and Managing the Behavior of Lunar Space Elevators

A Lunar Space Elevator (LSE) would be by many orders of magnitude the largest structures ever built and deployed by our civilization, with an expected tether length of well over 250,000 km. Even preliminary tethers deployed in CisLunar space, either for engineering tests or for Lunar sample return or for other scientific purposes, would likely exceed the diameter of the Earth in length and thus be the biggest mechanical structures ever created. Such "CisLunar" tethers will present novel problems of simulation, monitoring and control. Unlike conventional problems in orbital dynamics, which can be described by Ordinary Differential Equations (ODEs), the dynamics of CisLunar tethers will requiring modeling by Partial Differential Equations (ODEs). Mathematically the modeling of CisLunar tethers will have similarities to both Numerical Weather Forecasting (NWF) and the numerical modeling of large structures, such as bridges. CisLunar tethers will support a variety of oscillations and normal modes, excited by both gravitational perturbations and the motion of cargo vehicles along the tether, that are unlikely to be fully observed by any monitoring system; the techniques developed for NWF data assimilation are thus likely to be essential for the high capacity usage of an operational LSE. This presentation will describe the mathematical basis for CisLunar tether monitoring and operations and the current status of tether simulations.

Author: CHARLES RADLEY

ORAL

Missions (Including Commercial)

Minimalist lunar Helium-3 mining machine

There is considerable commercial potential for Helium-3 mining on the Moon. No one has built a working nuclear fusion reactor, yet there is much discussion of lunar Helium-3 (3He) isotope as nuclear fuel. Alas, the fusion market simply does not exist – and will not in a predictable timeframe. The fusion discussion has distracted the community from the market which already exists for 3He; a market which can be profitably supplied from the Moon more cheaply than from terrestrial sources. Surprisingly, since 2001 a strong new market has rapidly emerged. New demand has been driven by the US Department of Homeland Security, which needs 3He for neutron detectors at all seaports, airports and borders, to scan for nuclear material. Demand also increased from the medical sector (MRIs), and for natural gas exploration. Also, there is increasing demand from the oil and gas exploration sector from wireline well logging companies, and this demand currently receive top priority by the White House allocation committee. The US 3He stockpile came from the decay of nuclear warheads; it is dwindling rapidly. In 2008 the White House imposed 3He rationing to eke out remaining reserves and supply fell from 80,000 to 14,000 liters per year. Projected demand for 3He implies that U.S. production alone cannot meet anticipated worldwide demand. The price continues to increase. Current White House projections are that national He3 supplies will be completely depleted some time between 2025 and 2035. Supplies from Russia and Canada will not meet global demand. LiftPort is planning a proof of concept of a minimalist lunar helium-3 mining robot, approx 100 kg, based on the designs of the University of Wisconsin Fusion Technology Institute.As a by-product of Helium-3 mining, a large quantity of many other volatile gases will be produced all of which will be of benefit to NASA, commercial interests, and other international programs operations. Products developed include: water, carbon monoxide, carbon dioxide, and methane. These gases can be used for rocket propellant and to feed fuel cells to produce energy during the lunar night.The Helium-3 mining machine would be an apparatus mounted on a rover machine bus developed by one of the Google Lunar XPrize teams, there are several to choose from. The machine will be delivered to cislunar space via the NASA SLS and will soft land on the lunar surface. The system will be solar powered and will heat the regolith to liberate volatile gases. Fractional distillation will separate the Helium from the other constituent gases; then a superleak isotope enrichment process will separate the Helium-3 from the Helium-4.

Author: DENNIS WINGO

POSTER

Missions (Including Commercial)

ISEE-3 Reboot Project

The ISEE-3 Reboot Project was announced in Mid-April 2014. Our plan was simple: we intended to contact the ISEE-3 (International Sun-Earth Explorer) spacecraft, command it to fire its engines and enter an orbit near Earth, and then resume its original mission - a mission it began in 1978. Working in collaboration with NASA assembled a team of engineers, programmers, and scientists and made plans to utilize several large radio telescope to contact ISEE-3. The ultimate aim of the ISEE-3 Reboot Project was to facilitate the sharing and interpretation of all of the new data ISEE-3 sends back via crowd sourcing. NASA told us officially that there was no funding available to support an ISEE-3 effort - nor was this work a formal priority for the agency in the current budget environment. But NASA also said that any data that ISEE-3 might generate would have real value and that a crowd funded effort such as ours had real value as an education and public outreach activity. This activity was led by the same team that has successfully accomplished the Lunar Orbiter Image Recovery Project (LOIRP): SkyCorp and SpaceRef Interactive. Education and public outreach was to be coordinated by the newly-formed non-profit organization Space College Foundation. Our software team recreated lost hardware and software using “software radio”. We also amassed a collection of original program documentation. Our trajectory efforts were coordinated by experts associated with the ISEE-3 and LADEE missions. We will discuss the progress that the project has made to date and it implications for other collaborations NASA way wish to consider in the years ahead.

Author: DENNIS WINGO
POSTER

Missions (Including Commercial)

Lunar Orbiter Image Recovery Project

The Lunar Orbiter Image Recovery Project (LOIRP) was founded in 2007 to recover Lunar Orbiter mission imagery from original analog data tapes recorded as the images first arrived on Earth between 1966-1967. Funded with a mix of private and NASA money, we were able to rebuild original 50 year old FR-900 tape drives, build a modern version of the original demodulator, and recover imagery at previously unachieved resolution and dynamic range. We recovered our first image in November 2008, e enow-iconic "Earthrise" image taken by Lunar Orbiter 1 in August 1966. We completed to initial data recovery of all images from the 5 Lunar Orbiter missions in April 2014. All recovered imagery is currently being prepared for submittal to the NASA Planetary Data System. We will discuss the origin of the project, the technical and organizational challenges we encountered, the processes whereby we retrieve and archive our data, and how our imagery has been used since its recovery. We will also discuss the implications for other collaborations NASA way wish to consider in the years ahead.

Author: MARK ROBINSON
ORAL

Missions (Including Commercial)

Arne - Exploring the Mare Tranquillitatis Pit

Lunar mare "pits" are key science and exploration targets. The first three pits were discovered within Selene obser-vations [1,2] and were proposed to represent collapses into lava tubes. Subsequent LROC images revealed 5 new mare pits and showed that the Mare Tranquillitatis pit (MTP; 8.335°N, 33.222°E) opens into a sublunarean void at least 20-meters in extent [3,4]. Additionally more than 200 pits were discovered in impact melt deposits [4]. A key remaining task is determining pit subsurface extents, and thus fully understanding their exploration and scientific value. We propose a simple and cost effective reconnaissance of the MTP using a small lander (<130 kg) named Arne that carries three flying microbots (or pit-bots) each with mass of 3 kg [5,6,7]. Key measurement objectives include decimeter scale characterization of the structure of wall materials, 5-cm scale imaging of the eastern floor, determination of the extent of sublunarean void(s), and measurement of the magnetic and thermal environment. Arne will make a noontime descent and optically lock onto the MTP rim and floor shadow, 100 meters above the surrounding mare Arne will descend vertically (~1 m/s). At the top of the pit Arne will determine the position of boulders on the floor known from LROC images [3], and then maneuver to a relatively smooth spot in view of the Earth.After initial surface systems check Arne will transmit full resolution descent and surface images. Within two hours the first pit-bot will launch and fly into the eastern void. Depending on results from the first pit-bot the second and third will launch and perform follow-up observations (continue exploring same void or head west, north, and/or south). The primary mission is expected to last 48-hours, before the Sun sets on the lander there should be enough time to execute ten flights with each pit-bot.Arne will carry a magnetometer, thermometer, 2 high resolution cameras, and 6 wide angle cameras. The pit-bots are 30-cm diameter spherical flying robots [5,6,7]. Lithium hydride [5,6] and water/hydrogen peroxide power three micro-thrusters and achieve a specific impulse of up to 400 s. The same fuel and oxidizer is used for a fuel cell (en-ergy density of 2,000 Wh/kg) [5,6]. Each pit-bot can fly for 2 min at 2 m/s for more than 100 cycles; recharge time between cycles is 20 min. The pit-bots are equipped with a flash camera, magnetometer, thermometer and obstacle avoidance infrared sensors. [1] Haruyama et al. (2010) 41st LPSC, #1285. [2] Haruyama et al. (2010) GRL, 36, dx.doi.org/ 10.1029/2009GL0406355. [3] Robinson et al (2012) PSS, 69, dx.doi.org/ 10.1016/j.pss.2012.05.008 [4] Wagner and Robinson (2014) Icarus, in press. [5] Thangavelautham et al. (2012) IEEE ICRA [6] Strawser et al. (2014) J. Hydrogen Energy. [7] Dubowsky et al. (2007) Proc. CLAWAR.

Author: KATHERINE SHIRLEY
POSTER

Missions (Including Commercial)

Photometric Correction of the Diviner Thermal Channels

The Diviner Lunar Radiometer Experiment on board the Lunar Reconnaissance Orbiter is currently mapping multispectral thermal emission from the lunar surface [1]. Lunar surface composition is derived from the three narrow channels (channels 3-5) centered near 8 μm that determine the location of the Christiansen Feature (CF), which changes position as a function of silicate composition [2,3]. Diviner also maps the lunar surface at longer thermal wavelengths (12.5-400 μm; channels 6-9) that have not generally been used in mineralogical analyses. We have found that emissivity of the thermal channels varies as a function of solar incidence angle, generally giving lower emissivity values at higher incidence angles. A correction has been developed for the 8 μm channels which normalizes all Diviner daytime data to 0° incidence angles at the equator [4]; however, a correction for the thermal channels has yet to be developed. Here we describe our simple "bootstrap" approach to photometrically correct these channels.Methods: Our correction assumes that the data measured at an incidence angle of 0° is ideal. Thus, we first examine relatively homogenous locations on the Moon determined using a global map of CF values [e.g. 3], and obtain an average emissivity measurement for each. Because we assume that 0° incidence measurements are correct, the slopes between channels at this incidence angle are also taken to be true. These slopes are then projected onto the previously corrected emissivity measurements starting at channel 5 to predict values at channel 6, and so on for higher incidence angle measurements.Slopes from emissivity data from two locations (one mare, one highlands) were used to create two versions of a correction, which was then applied globally and tested at several locations in both mare and highlands areas (basaltic or felsic, respectively) and at varying coordinates.Results: We found that this type of correction improves the data measured at higher incidence angle. It does tend to overcorrect if applied to a location of different composition than the correction location used (i.e. a mare correction should be applied to only mare region). Conclusions/Future Work: This simple correction is working well in normalizing higher solar incidence angle emissivity to that obtained at a 0° incidence angle. Next, we will combine the current corrections to apply compositionally specific corrections which should fix the observed overcorrections. Eventually, another version of the correction will use the emissivity data per pixel at 0° incidence to correct the high incidence angle data. The thermal channels can then be used to give more detailed insight into surface mineralogy by increasing the amount of compositionally useful channels from 3 to 7. This could allow us to create mineral spectral indices and use spectral unmixing models.

Author: J.R. SKOK

Missions (Including Commercial)

ORAL

Mojave Volatiles Prospector – Water in the Mojave Desert as an Analog to the Lunar Poles

The Mojave Volatiles Prospector (MVP) project is a science-driven field program with the goal to produce critical knowledge for conducting robotic exploration of the Moon. MVP will feed science, payload, and operational lessons learned to the development of a real-time, short-duration lunar polar volatiles prospecting mission. MVP will achieve this through a simulated lunar rover mission to investigate the composition and distribution of surface bound and sub-surface volatiles in a natural and a priori unknown environment, improving our understanding of how to find, characterize, and access volatiles on the Moon.The science of MVP is driven by the possibility that water ice deposits exist in permanently shaded regions (PSRs) near both lunar poles (Watson et al. 1961; Arnold 1979). The floors of such craters should be extremely cold (<100K) (Vasavada et al. 1999). LRO Diviner has measured some PSRs colder than 40K. The Lunar Crater Observation and Sensing Satellite (LCROSS) mission measured ~5 wt% water in Cabeus crater (Colaprete et al. 2010). However, the distribution of water and other volatiles is unknown at scales less than a few tens of km. If cold-trapped volatiles are concentrated in limited areas, orbital techniques will not be sufficient to localize them. Only by exploring the surface can we determine the presence, abundance, composition and spatial distribution of cold-trapped volatiles. MVP will integrate three instruments: the Near Infrared and Visible Spectrometer Subsystem (NIRVSS), Neutron Spectrometer Subsystem (NSS), and a downward facing GroundCam camera on the KREX-2 rover to investigate the relationship between the distribution of volatiles (detected by NIRVSS and NSS) and soil crust variation (observed by GroundCam). Through this investigation, we will mature robotic in situ instruments and concepts of instrument operations, improve ground software tools for real time science, and carry out publishable research on the water cycle and its connection to geomorphology and mineralogy in desert environments.Our field site is the Mojave Desert, selected for its low, naturally occurring water abundance. The Mojave typically has on the order of 2-6% water (Webb 2002), making it a suitable analog for this field test. NIRVSS and NSS are specifically designed for detecting low water abundances. A lunar polar rover mission is unlike prior human or robotic missions and requires a new concept of operations. The rover must navigate 3-5 km of terrain and examine multiple sites in a very short time (Heldmann et al. 2012). Operational decisions must be made in real time, requiring constant situational awareness, fast data analysis and quick-turnaround decision support tools. This is unlike the daily command cycles and intermittent communications with Mars rovers, or rehearsed procedure execution of manned spaceflight. MVP will involve a small field team in the Mojave and a scientific and operational backroom team at NASA Ames. The operational and communications architectures between these teams will serve as a foundation for the development of decisional frameworks and operational concepts of future lunar rover missions.

SSERVI-ESF14-202

Author: ANGELA STICKLE

POSTER

Missions (Including Commercial)

Illumination Simulations for Long Duration Landed Missions to the Lunar Poles

Recent missions to the Moon acquired global high-resolution topography data of the lunar surface. These data are of sufficient quality that they can be used to simulate illumination conditions on the lunar surface for any sun location with confidence and thus can be used to create detailed simulations of illumination conditions during future missions. We have developed a software tool, LunarShader, which precisely simulates lunar illumination conditions through the use of a fixed sun position and a gridded topographic image file. The output of the model is a second gridded image file that contains the percentage of sun available to each pixel. The simulation is run over a set period of time (e.g., the year from 10/22/2018 to 10/22/2019) with a constant time difference between each image (here, we are looking at 1-hr intervals). These illumination data can be used to derive parameters of interest for planning lunar lander or rover missions, including: longest period of continuous illumination, longest period of shadow, mean illumination, permanently shadowed regions, and earth-visibility maps. In this study, these data are used to identify areas of the lunar North Pole that could support a future mission continuously in sunlight. For a 30-m spatial resolution and a 1-hr time resolution, regions on the North Pole of the Moon (above 75° latitude) receiving a high percentage of average illumination over a one-year time period were identified. The three regions with the highest percent illumination are all illuminated for 75-90% of the year. The highest average illumination is 85.75% for a region on the edge of Whipple crater (on the edge of Peary crater). Using these data, we developed an algorithm to keep a potential landed rover constantly in sunlight assuming the rover could move at average rover speeds (e.g., 30-90m/hr). We track the percent sunlight at the simulated rover's current position, and if within two hours the current position will transition into shadow, the simulated rover will examine surrounding areas and move to a sunlit region. If more than one nearby pixel is sunlit, the rover will move to the nearest area with the longest period of continuous sunlight. This alleviates the need for large amounts of batteries and allows for a long-term landed mission powered solely by solar panels.

Author: JUERGEN THIEME
ORAL

Missions (Including Commercial)

X-ray spectroscopy with high spatial resolution – the SRX beamline at NSLS-II

X-ray spectromicroscopy is a very useful way of combining high spectral with high spatial resolution. The smallest structures visible in an X-ray microscope at present are below 10 nm size. X-ray microscopy is capable of imaging specimens directly, even in aqueous media; there is no need for fixation or staining. Due to the refractive index of matter being close to unity, clear images without scattering background are obtained even when studying thick and inhomogeneous samples. Therefore, X-ray microscopy images can be used for tomographic reconstructions of thick samples. By choosing the used X-ray energy appropriately, it is possible to perform spectromicroscopy studies. X-ray fluorescence can be used as a highly sensitive method to identify trace elements. Comprising, the combination of microscopy and spectroscopy enables studies of structures showing dimensions on the nanoscale, e.g. the composition of interplanetary dust particles, and is a powerful way for addressing key questions in many scientific areas. An electron storage ring, being an X-ray light source of extreme brightness, is the site of installation for an X-ray spectromicroscopy station. The National Synchrotron Light Source II promises to be the world's leading light source for such a station. Its source characteristics are ideally suited for experiments in need of coherence and provides an ideal platform for sub-μm focused beam instruments. The Sub-micrometer Resolution X-ray spectroscopy beamline (SRX) at NSLS-II has been developed specifically as an X-ray fluorescence analytical probe, allowing for the study of chemical and physical properties of complex systems even on trace elemental concentration levels. The scientific emphasis is the study of such systems with chemical heterogeneities at sub-μm and sub-100nm length scales. The beamline will provide X-ray spectroscopy capabilities in the energy range from 4.65keV to 23keV. SRX utilizes two sets of Kirkpatrick-Baez mirror optics for focusing, a high-flux setup that will deliver more than 10^13 phot/sec in a sub-μm spot and a high-resolution setup that will deliver a focal spot size of less than 100nm at a flux of approximately 10^11 phot/sec. The energy range covered will allow for X-ray spectroscopy experiments starting at the K-absorption edge of titanium and extending through the K-edge of rhodium, thus embracing a large section of the periodic table of elements. The photon flux SRX delivers in a sub-μm spot, ultimately combined with the use of new energy dispersive detectors like the MAIA, will open new possibilities for spectroscopic analysis of major and trace elements in natural and synthetic materials, X-ray fluorescence imaging of their distribution both in 2D and 3D, and concurrent μ-diffraction measurements. Coherent diffraction imaging experiments will be developed as well. Commissioning of the beamline will begin in fall 2014; first scientific experiments are planned for the beginning of 2015.

Author: DAVID WILLIAMS
POSTER

Missions (Including Commercial)

.Lunar Data Project/Lunar Data Node: Apollo Data Restoration Update

The Apollo Lunar Surface Experiments Packages (ALSEPs) on Apollo 12, 14, 15, 16, and 17 returned data from the lunar surface until September 1977. These long-term in-situ data, along with data from Apollo surface and orbital experiments, still comprise some of the best information on the Moon's environment. Much of these data were archived at the National Space Science Data Center (now the NASA Space Science Data Coordinated Archive, NSSDCA) in the 1970's and 1980's, but a large portion of the data were never submitted. The data that were archived were generally on microfilm and microfiche, or on magnetic tapes in obsolete formats, making them difficult to use today. And in many cases the documentation and other ancillary information (metadata) are insufficient to allow for proper scientific use of these data. We report on the efforts of the Lunar Data Project, to: 1) put the archived data into digital formats to make them more easily obtainable and readable; 2) search for and recover data which were never archived and bring them into the NSSDCA; and 3) compile the appropriate metadata to accompany these data sets. Data sets which are completed in this way are archived with the Planetary Data System (PDS) through the Lunar Data Node at the NSSDCA under the auspices of the PDS Geosciences Node.Nine lunar data sets have been fully restored and archived through PDS from the Apollo 12 and 15 Solar Wind Spectrometer, the Apollo 14 and 15 Cold Cathode Ion Gage, the Apollo 17 Traverse Gravimeter, and the Apollo 15 and 16 Soil Mechanics Penetrometer. A number of data sets have been restored and submitted for PDS review and are now in lien resolution: Apollo 14 and 15 Dust Detector, Apollo 15 and 17 Heat Flow, and the Apollo 15 and 16 X-Ray Spectrometer. We are currently in the process of restoring data from a large number of Apollo experiments, including the Apollo 17 Lunar Ejecta and Meteorites Experiment, the Apollo 11 and 12 Dust Detector Experiments, the Apollo 16 Active Seismic Experiment, the Apollo 17 Lunar Atmospheric Composition Experiment, the Apollo 14 Charged Particle Lunar Environment Experiment, the Apollo 14 and 15 Suprathermal Ion Detector Experiment, the Apollo 17 Infrared Radiometer, and the Apollo orbital and surface magnetometers.We are also working on new data sets as part of proposals funded by LASER, including the ALSEP ARCSAV (Telemetry) tapes, the ALSEP Housekeeping data, the Apollo 15 and 16 Mass Spectrometer data, the Apollo 17 Far-UV Spectrometer data, the Apollo 15, 16, and 17 Photography Indexes, the Apollo 17 Surface Electrical Properties Experiment, and the Apollo 14 and 15 Gamma-Ray Spectrometer. We continue to look for unarchived data and metadata from many experiments, including the Heat Flow, Lunar Ejecta and Meteorite, and Lunar Surface Gravimeter. This presentation will give an update of our efforts. The fully restored data sets are available online at the PDS Geosciences Node: http://geo.pds.nasa.gov/missions/apollo/index.htm

SSERVI-ESF14-205

Author: ROBERT WINGLEE

ORAL

Missions (Including Commercial)

Sample Return using High Velocity Penetrators

There have only been a few sample return missions since the start of the space age. Their limited number reflects their high cost, with the most recent missions taking only small surface samples. This paper reports results from the development of a high velocity (150-600 m/s) penetrator that is able to take a core sample down to a few meters, and requires simpler orbital maneuvers to reduce the mass and cost requirements of a sample return mission. The penetrator is able to survive the high velocity impact through innovations associated with energy absorbing material that support the sample return container. Material for the solar system object move through a central feed system. Extraction of the sample is via an attached tether system that is used to both reduce the Delta V of the impact and return the sample to main spacecraft. Examples of survivability through impacts in playa and in rocky material are presented along with an overall mission scenario.

Author: KRIS ZACNY

ORAL

Missions (Including Commercial)

IceBreaker Drill

One of the main goals of the Icebreaker Mission to Mars is to search for evidence of life on the planet. To enable the search, a sample of ground ice needs to be acquired and transferred into a life detection instrument. Samples need to be acquired from depths greater than approximately one meter; that is below the range of harmful radiation that reaches the surface of Mars. Since the 1990s, we have been developing drilling technologies for reaching below one meter depth on various planetary bodies, including Mars and the Moon. The drilling approaches included rotary, percussive, sonic, and ultrasonic. The most promising one was percussive and it was selected for the IceBreaker3. The IceBreaker3 drill is at TRL 5/6 and weighs approximately 10 kg.The IceBreaker3 drill captures cuttings rather than the core. This greatly simplifies sample handling and the drill itself. The sample is captured in a 'bite' approach that is after drilling a 10 cm interval, the drill is pulled out and sample transferred into an instrument via one of three methods . While the sample is being analyzed, the drill is in a safe position above the ground. To capture next sample, the drill is inserted into the same hole and after reaching hole bottom, captures next 10 cm sample. This method allows preservation of stratigraphy. The drill serves as a 'science' instrument as well. The telemetry can be used to assess strength of the formation and identify ice lenses. The bit temperature can be used to plot thermal gradient to 1 m depth, and potentially determine heat flow property of the planet. The drill could also be used on other planetary bodies, such as the Moon, for acquisition of dry or icy regolith for In Situ Resource Utilization (ISRU) missions.The IceBreaker videos can be watched here: https://www.youtube.com/watch?v=fTNPokiXa0E and https://www.youtube.com/watch?v=QE7aYUnAA9o